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ABSTRACT

This information sheet: (1) lists and describes basic science process skills (observing, inferring, measuring, communicating, classifying, and predicting); (2) lists and describes integrated science process skills (controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, and formulating models); and (3) provides findings from selected research studies dealing with the learning of these skills. In general, the research literature indicates that when science process skills are a specific planned outcome of a science program, those skills can be learned by students. Therefore, it is suggested that teachers need to select curricula which emphasize science process skills and to capitalize on opportunities to practice those skills in the activities normally done in the classroom. (JN)

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Research Matters...To the Science Teacher

THE SCIENCE PROCESS SKILLS

Michael J. Padilla

One of the most important and pervasive goals of schooling is to teach students to think. All school subjects should share in accomplishing this overall goal. Science contributes its unique skills, with its emphasis on hypothesizing, manipulating the physical world and reasoning from data.

The scientific method, scientific thinking and critical thinking have been terms used at various times to describe these science skills. Today the term "science process skills" is commonly used. Popularized by the curriculum project, Science - A Process Approach (SAPA), these skills are defined as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behavior of scientists. SAPA grouped process skills into two types—basic and integrated. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills. These skills are listed and described below.

Basic science process skills

Observing - using the senses to gather information about an object or event. Example: Describing a pencil as yellow.

Inferring - making an "educated guess" about an object or event based on previously gathered data or information. Example: Saying that the person who used a pencil made a lot of mistakes because the eraser was well worn.

Measuring - using both standard and nonstandard measures or estimates to describe the dimensions of an object or event. Example: Using a meter stick to measure the length of a table in centimeters.

Communicating - using words or graphic symbols to describe an action, object or event. Example: Describing the change in height of a plant over time in writing or through a graph.

Classifying - grouping or ordering objects or events into categories based on properties or criteria. Example: Placing all rocks having a certain grain size or hardness into one group.

Predicting - stating the outcome of a future event based on a pattern of evidence. Example: Predicting the height of a plant in two weeks time based on a graph of its growth during the previous four weeks.

Integrated science process skills

Controlling variables - being able to identify variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable. Example: Realizing through past experience that amount of light and water need to be controlled when testing to see how the addition of organic matter affects the growth of beans.

Defining operationally - stating how to measure a variable in an experiment. Example: Stating that bean growth will be measured in centimeters per week.

Formulating hypotheses - stating the expected outcome of an experiment. Example: The greater the amount of organic matter added to the soil, the greater the bean growth.

Interpreting data - organizing data and drawing conclusions from it. Example: Recording data from the experiment on bean growth in a data table and forming a conclusion which relates trends in the data to variables.

Experimenting - being able to conduct an experiment, including asking an appropriate question, stating a hypothesis, identifying and controlling variables, operationally defining those variables, designing a "fair" experiment, conducting the experiment, and interpreting the results of the experiment. Example: The entire process of conducting the experiment on the affect of organic matter on the growth of bean plants.

Formulating models - creating a mental or physical model of a process or event. Example: The model of how the processes of evaporation and condensation interrelate in the water cycle.

Learning basic process skills

Numerous research projects have focused on the teaching and acquisition of basic process skills. For example, Padilla, Cronin, and Twiest (1985) surveyed the basic process skills of 700 middle school students with no special process skill training. They found that only 10% of the students scored above 90% correct, even at the eighth grade level. Several researchers have found that teaching increases levels of skill performance. Thiel and George (1976) investigated predicting among third and fifth graders, McKenzie and Padilla (1987) graphing among eighth graders, and Tomera (1974) observing among seventh graders. From these studies it can be concluded that basic skills can be taught and that, when learned, readily transfered to new situations (Tomera, 1974). Teaching strategies which proved effective were: (1) applying a set of specific rules for predicting, (2) using activities and pencil and paper simulations to teach graphing, and (3) using a combination of explaining, practice with objects, discussions and feedback with observing. In other words—just what

research and theory has always defined as good teaching.

Other studies evaluated the effect of NSF-funded science curricula on how well they taught basic process skills. Studies focusing on the Science Curriculum Improvement Study (SCIS) and SAPA indicate that elementary school students, if taught process skills abilities, not only learn to use those processes, but also retain them for future use. Researchers, after comparing SAPA students to those experiencing a more traditional science program, concluded that the success of SAPA lies in the area of improving process oriented skills (Wideen, 1975; McGlathery, 1970). Thus it seems reasonable to conclude that students learn the basic skills better if they are considered an important object of instruction and if proven teaching methods are used.

Learning integrated process skills

Several studies have investigated the learning of integrated science process skills. Allen (1973) found that third graders can identify variables if the context is simple enough. Both Quinn and George (1975) and Wright (1981) found that students can be taught to formulate hypotheses and that this ability is retained over time.

Others have tried to teach all of the skills involved in conducting an experiment. Padilla, Okey and Garrard (1984) systematically integrated experimenting lessons into a middle school science curriculum. One group of students was taught a two week introductory unit on experimenting which focused on manipulative activities. A second group was taught the experimenting unit, but also experienced one additional process skill activity per week for a period of fourteen weeks. Those having the extended treatment outscored those experiencing the two week unit. These results indicate that the more complex process skills cannot be learned via a two week unit in which science content is typically taught. Rather, experimenting abilities need to be practiced over a period of time.

Further study of experimenting abilities shows that they are closely related to the formal thinking abilities described by Piaget. A correlation of +.73 between the two sets of abilities was found in one study (Padilla, Okey and Dillashaw, 1983). In fact, one of the ways that Piaget decided whether someone was formal or concrete was to ask that person to design an experiment to solve a problem. We also know that most early adolescents and many young adults have not yet reached their full formal reasoning capacity (Chiapetta, 1976). One study found only 17% of seventh graders and 34% of twelfth graders fully formal (Renner, Grant and Sutherland, 1978).

What have we learned about teaching integrated science processes? We cannot expect students to excell at skills they have not experienced or been allowed to practice. Teachers cannot expect mastery of experimenting skills after only a few practice sessions. Instead students need multiple opportunities to work with these skills in different content areas and contexts. Teachers need to be patient with those having difficulties, since there is a need to have developed formal thinking patterns to successfully "experiment."

Summary and conclusions

A reasonable portion of the science curriculum should emphasize science process skills according to the National Science Teachers Association. In general, the research literature indicates that when science process skills are a specific planned outcome of a science program, those skills can be learned by students. This was true with the SAPA and SCIS and other process skill studies cited in this review as well as with many other studies not cited.

Teachers need to select curricula which emphasize science process skills. In addition they need to capitalize on opportunities in the activities normally done in the classroom. While not an easy solution to implement, it remains the best available at this time because of the lack of emphasis of process skills in most commercial materials.

References

Allen, L. 1973. An examination of the ability of third grade children from the Science Curriculum Improvement Study to identify experimental variables and to recognize change. *Science Education*, 57, 123-151.

Chiapetta, E. 1976. A review of Piagetian studies relevant to science instruction at the secondary and college level. *Science Education*, 60, 253-261.

McGlathery, G. 1970. An assessment of science achievement of five and six-year-old students of contrasting socio-economic background. *Research and Curriculum Development in Science Education*, 7023, 76-83.

McKenzie, D., & Padilla, M. 1984. Effect of laboratory activities and written simulations on the acquisition of graphing skills by eighth grade students. Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans.

Padilla, M., Okey, J., & Dillashaw, F. 1983. The relationship between science process skills and formal thinking abilities. *Journal of Research in Science Teaching*, 20.

Padilla, M., Cronin, L., & Twiest, M. 1985. The development and validation of the test of basic process skills. Paper presented at the annual meeting of the National Association for Research in Science Teaching, French Lick, IN.

Quinn, M., & George, K. D. 1975. Teaching hypothesis formation. *Science Education*, 59, 289-296.

Renner, J., Grant, R., & Sutherland, J. 1978. Content and concrete thought. *Science Education*, 62, 215-221.

Thiel, R. & George, D. K. 1976. Some factors affecting the use of the science process skill of prediction by elementary school children. *Journal of Research in Science Teaching*, 13, 155-166.

Tomera, A. 1974. Transfer and retention of transfer of the science processes of observation and comparison in junior high school students. *Science Education*, 58, 195-203.

Wideen, M. 1975. Comparison of student outcomes for Science - A Process Approach and traditional science teaching for third, fourth, fifth and sixth grade classes: A product evaluation. *Journal of Research in Science Teaching*, 12, 31-39.

Wright, E. 1981. The long-term effects of intensive instruction on the open exploration behavior of ninth grade students. *Journal of Research in Science Teaching*, 18.

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